Trajectory-based change detection in forests: *Tapping the latent information of the TM/ETM+ archive*

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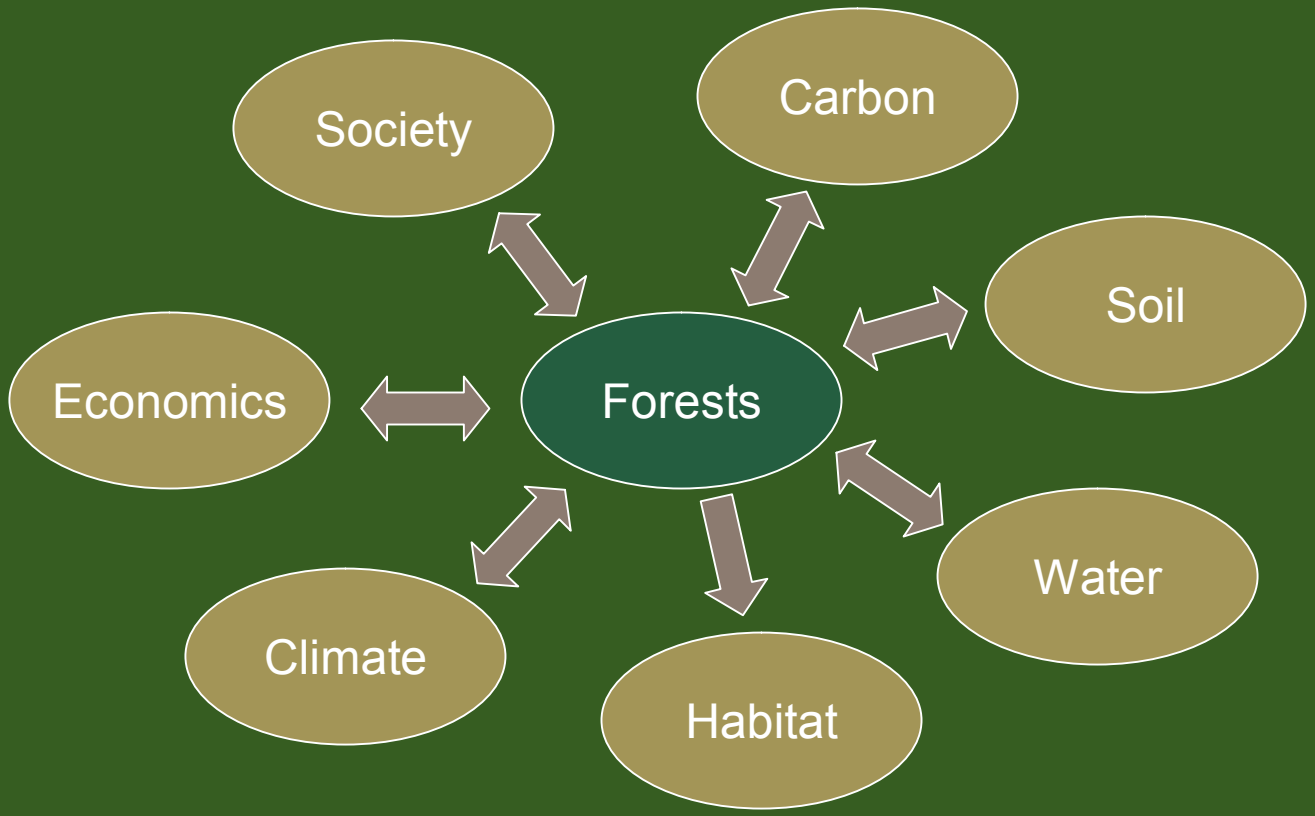
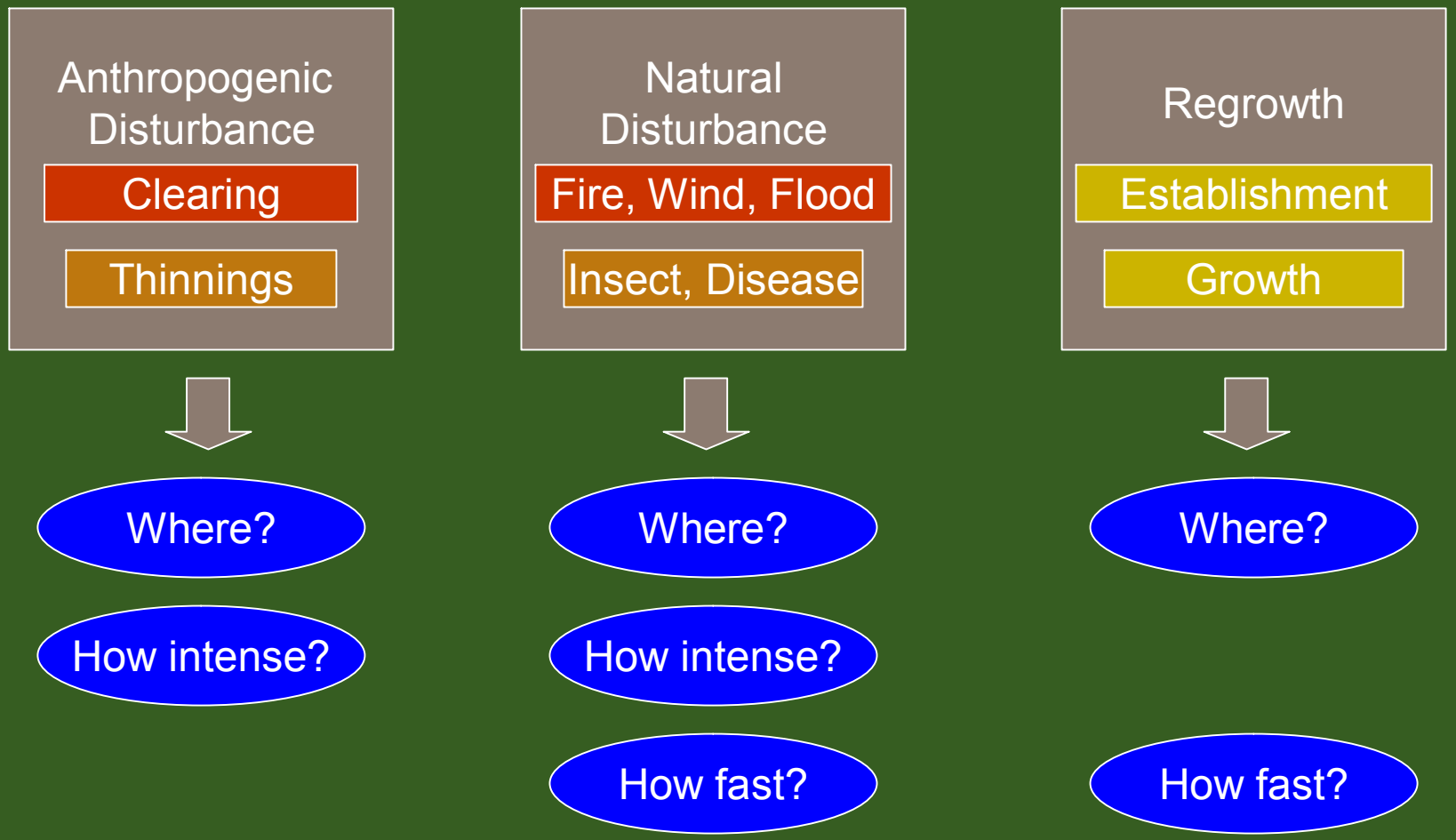
Change detection in the Woodcockian era

- Evolving context:
  - Expanding data access
  - Increasingly cheap data storage and analysis
  - Emerging synergies in sensors, institutions, etc.
- Change detection methods must move toward:
  - **Automation** (thresholding and labeling)
  - **Extension** (site specific solutions are out)
  - **Richness** (leverage sensor and temporal depth)

Test case: Forests

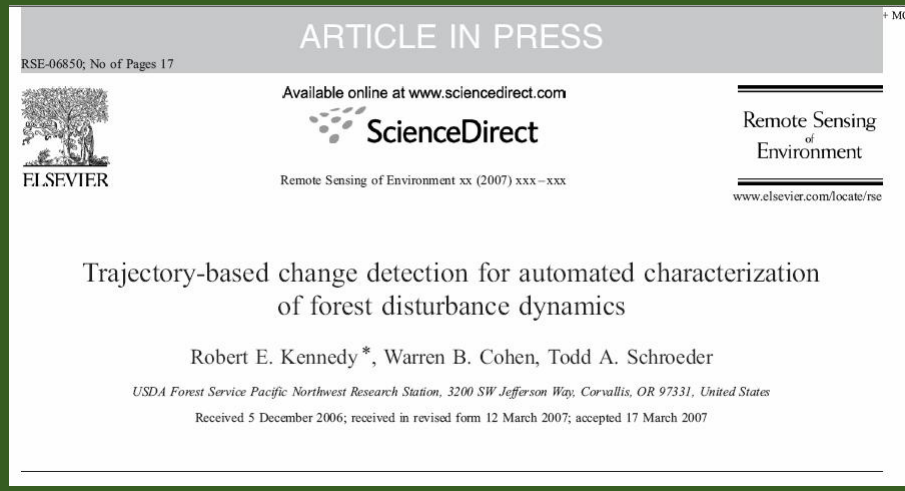


Changes of interest in forests



Trajectory-based approach*

- Rather than look for disturbance EVENTS, look for disturbance TRAJECTORIES
  - Characteristic spectral patterns before and after disturbance
  - Develop idealized curves and describe with simple functions



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Trajectory-based change detection for automated characterization of forest disturbance dynamics

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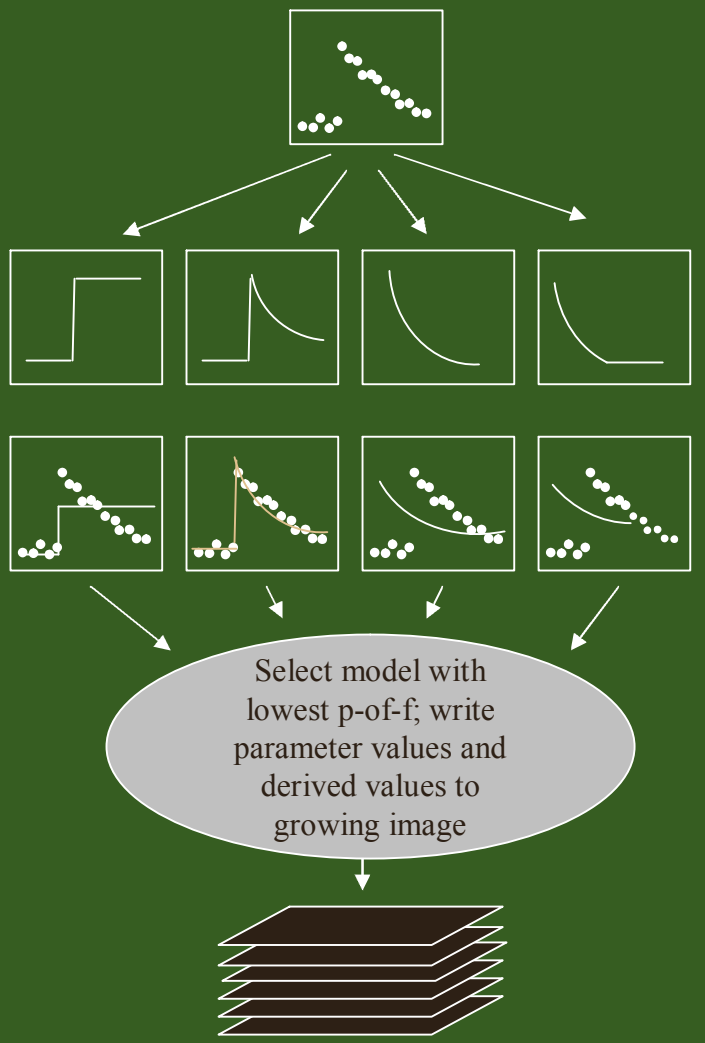
- Thresholds of change are statistical rather than data-specific
  - Goodness of fit to idealized curves

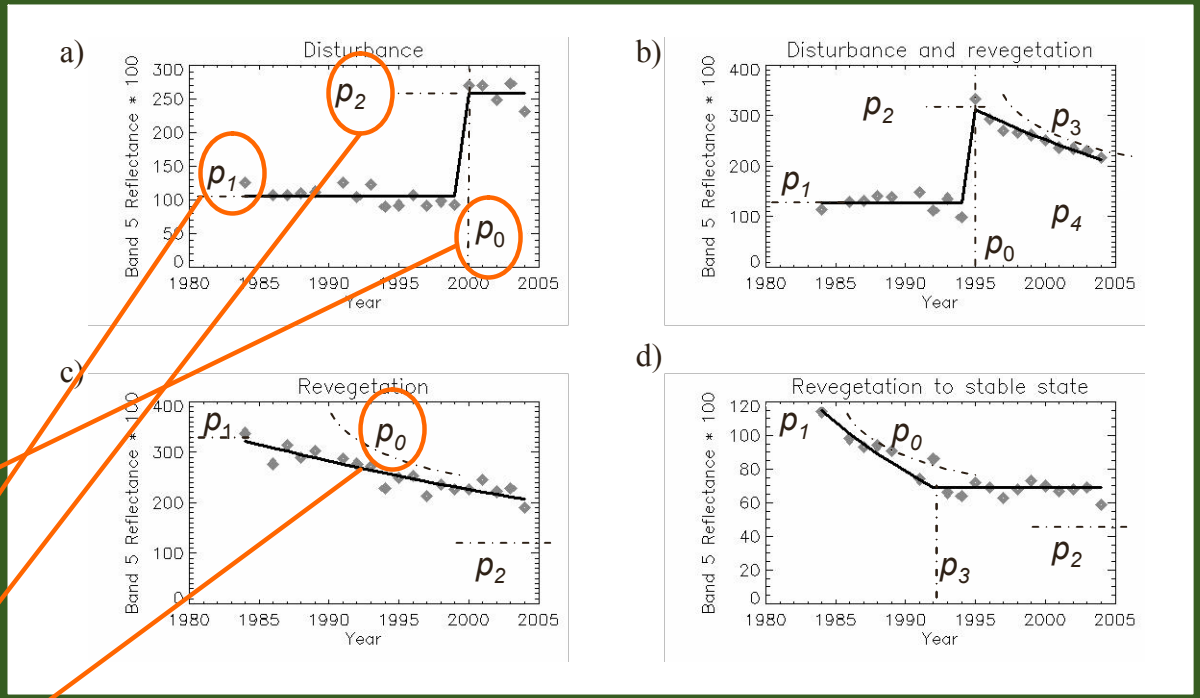
Trajectory modeling

- Extract SWIR band from yearly stack of Landsat imagery
- For each pixel, compare four idealized trajectories to the observed trajectory
- Select model with lowest p-of-f, write parameter values to file



Idealized trajectories

- Parameters describing function also describe disturbance
- Outputs:
  - Year of disturb.
  - Pre-dist. mean
  - Intensity
  - Recovery rate



Testing: Landsat Path 46 Row 29

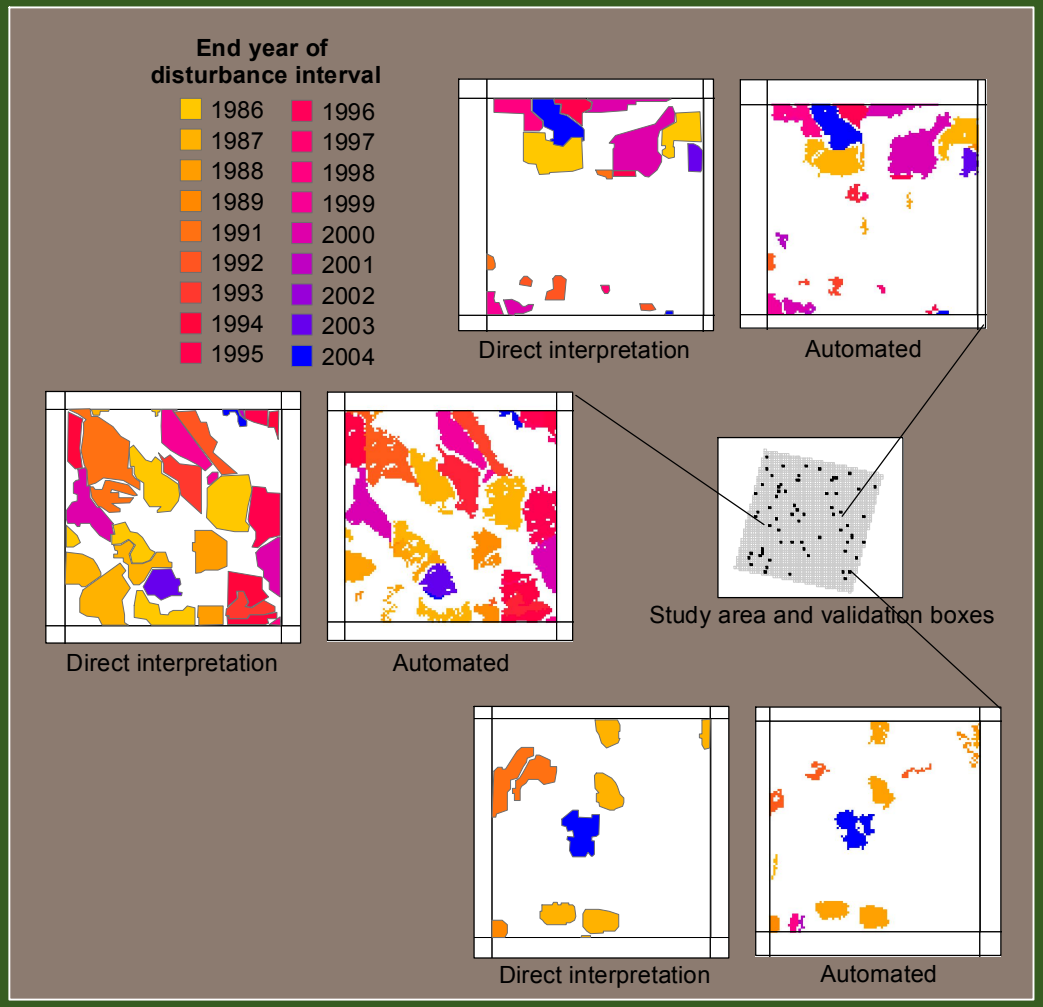


Table 5. Plot-level* accuracy of trajectory-based change detection

		Interpreted		
		No change	Change	Users accuracy
Algorithm	No change	455	97	0.82
	Change	45	403	0.90
	Producers accuracy	0.91	0.81	

Overall users accuracy	0.86	Overall accuracy	0.86
Overall producers accuracy	0.86	Kappa coefficient	0.72

* Plots are 9-pixel contiguous blobs randomly distributed in equal counts in interpreted change and no-change areas

Clear-cuts: Year of disturbance captured

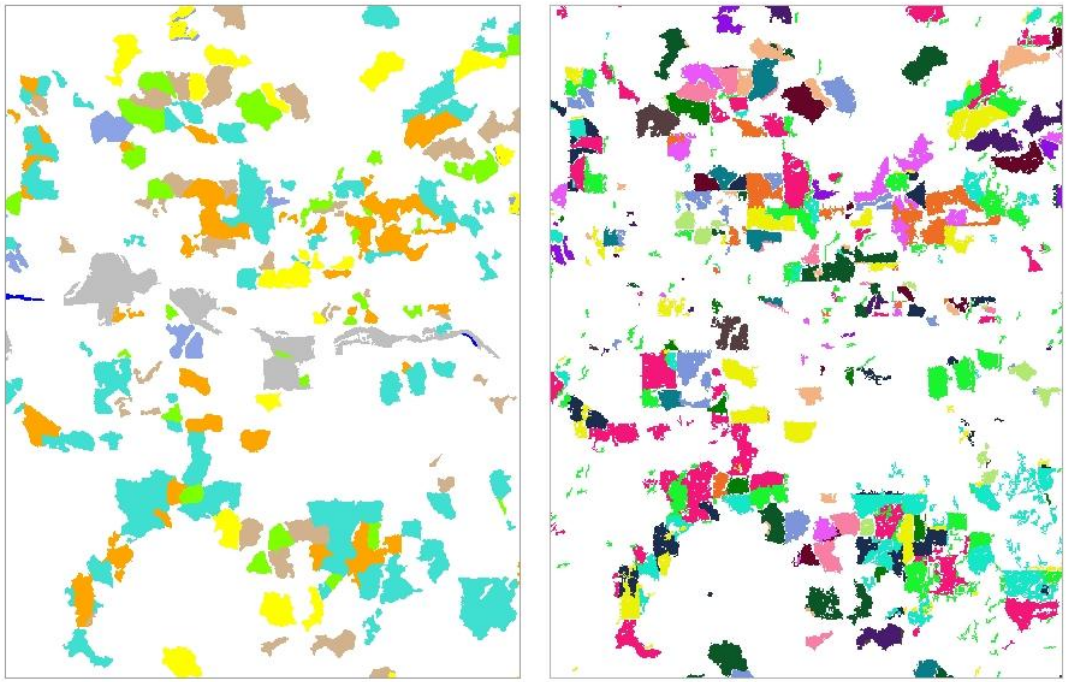
Table 7. Plot-based agreement between interpreted and algorithm-derived labeling of disturbance year for Type 1 disturbances (clearcuts) only.

		Interpreted																			Users Accuracy
		*NC**	*1986*	*1987*	*1988*	*1989*	*1991*	*1992*	*1993*	*1994*	*1995*	*1996*	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*	
Algorithm	*NC**	471	11	4	2	1	6	2	0	2	2	1	1	0	0	2	0	0	0	2	0.93
	1986	4	35	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0.88
	1987	4	2	30	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.81
	1988	3	0	0	36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.92
	1989	0	0	0	0	20	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0.95
	1991	2	1	0	0	0	55	0	0	0	0	0	0	0	0	0	0	0	0	0	0.95
	1992	4	0	0	0	0	0	22	0	0	0	0	0	0	0	0	0	0	0	0	0.85
	1993	2	0	0	0	0	0	1	18	0	0	0	0	0	0	0	0	0	0	0	0.86
	1994	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	1.00
	1995	0	0	0	0	0	0	0	0	0	26	0	0	0	0	0	0	0	0	0	1.00
	1996	2	0	0	0	0	0	0	0	1	0	23	0	0	0	0	1	0	0	0	0.85
	1997	6	0	0	0	0	0	0	0	0	0	1	13	0	0	0	0	0	0	0	0.65
	1998	2	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0.78
	1999	2	0	0	0	0	0	2	0	0	0	0	0	0	21	0	0	0	0	0	0.84
	2000	2	0	0	0	0	0	0	0	0	0	0	0	0	0	43	5	1	0	0	0.84
	2001	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0	0.86
	2002	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	19	0	0	0.95
	2003	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18	0	0.95
	2004	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	29	0.88
Producers accuracy		0.92	0.71	0.88	0.92	0.95	0.89	0.81	1.00	0.70	0.93	0.92	0.93	1.00	1.00	0.96	0.63	0.95	0.90	0.94	

Overall users accuracy 0.88 Overall accuracy 0.91

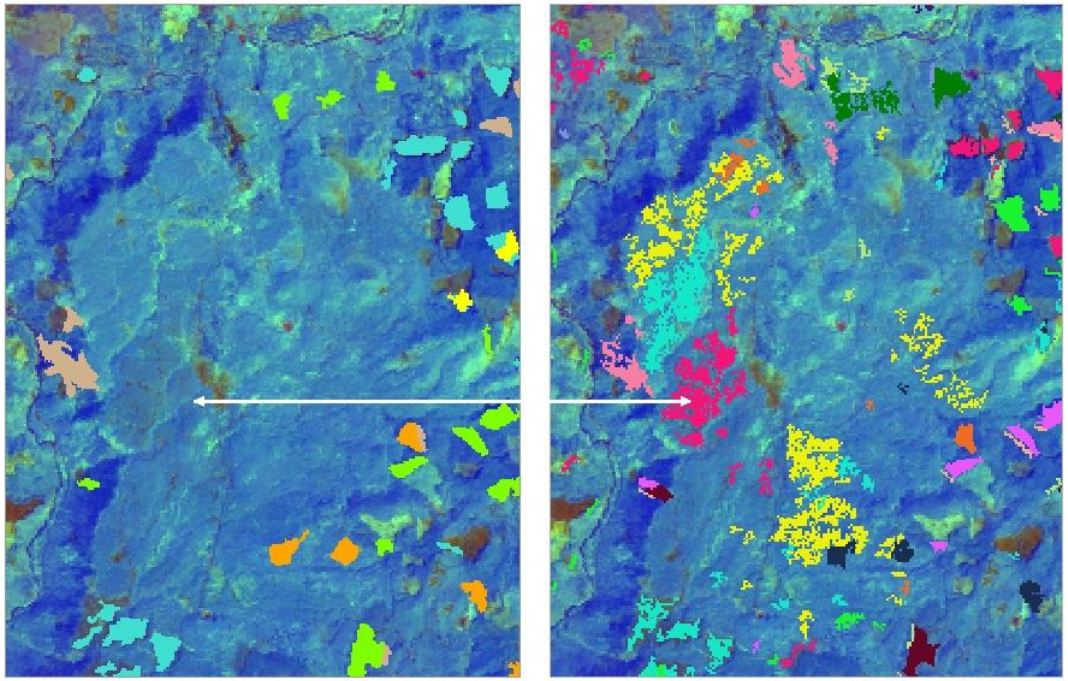
Overall producers accuracy 0.89 Kappa coefficient 0.87

Year of disturbance captured



Subtle disturbance captured

Trajectory-based change detection: Detection of thinning

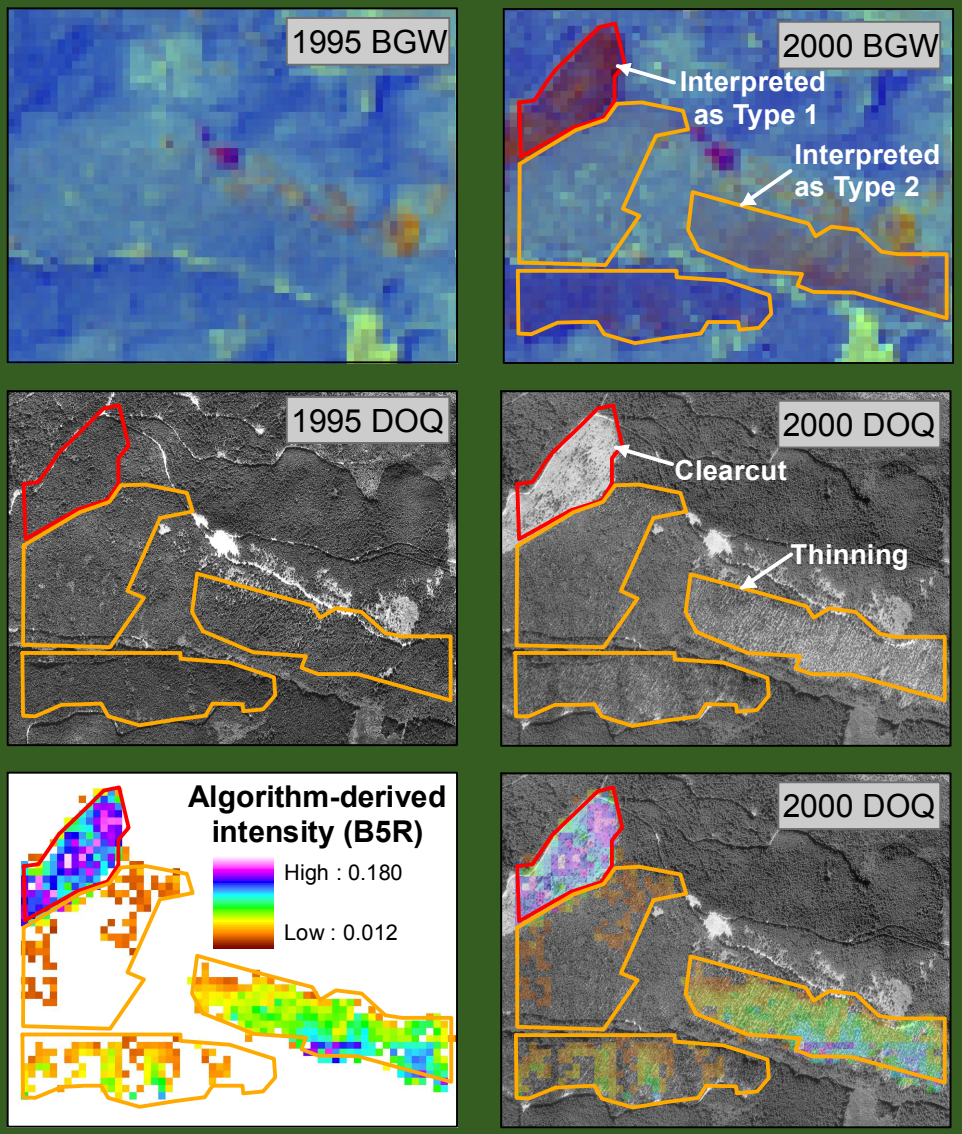


Existing disturbance map:
3-5 year intervals

Trajectory-based disturbance:
Yearly intervals

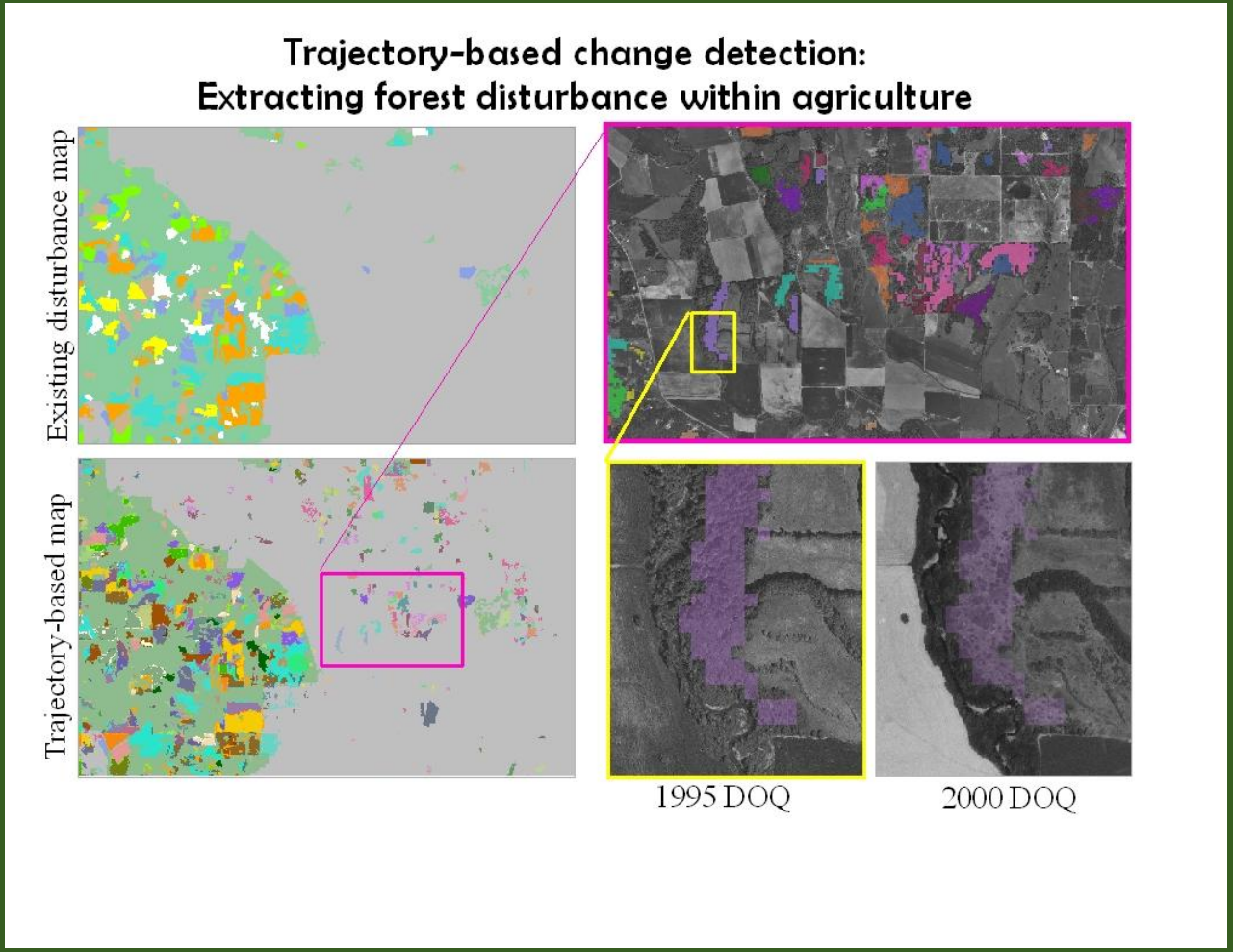
Key result

- Trajectory approach detected and labels subtle forest disturbance well
- **Increased signal-to-noise ratio of dense time series data**



Forest change within agricultural context

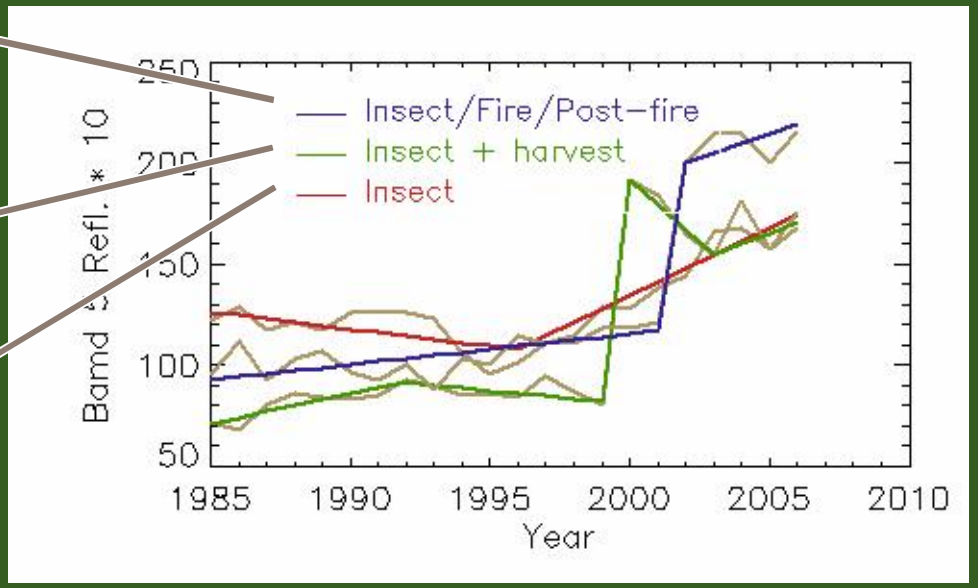
- No need for *a priori* determination of forest population
- Year-to-year variation in agriculture is noise; coherent trajectory in forests in signal



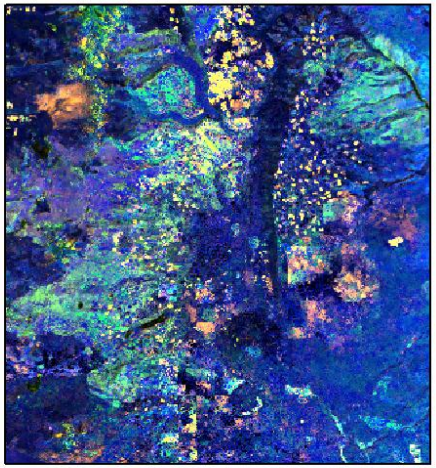
Ongoing work

- Expansion:
  - Move beyond small number of idealized curves
    - Segmenting time series
- Improve speed of processing
- Apply to NAFD project sample scenes

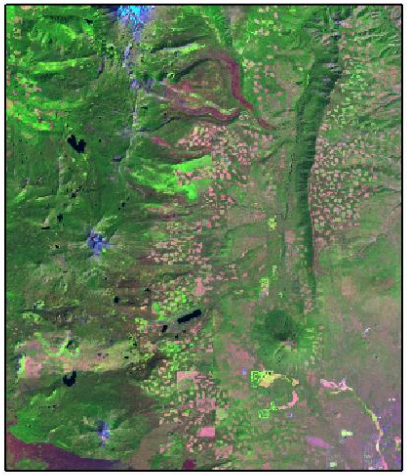
Trajectory segmentation



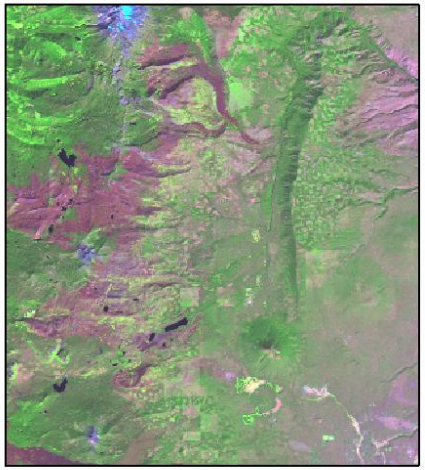
Trajectory segmentation



Most recent disturbance:
R: Loss Rate G: Abs. Loss
B: Pre-dist. Val.

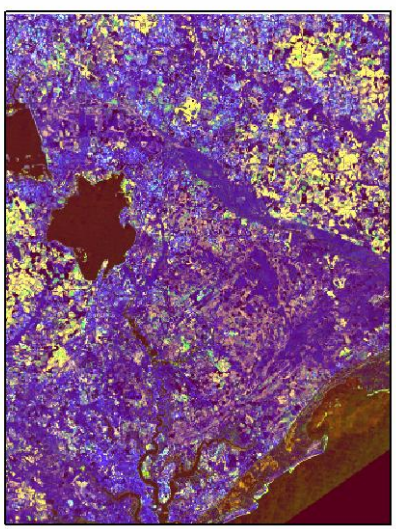


1990

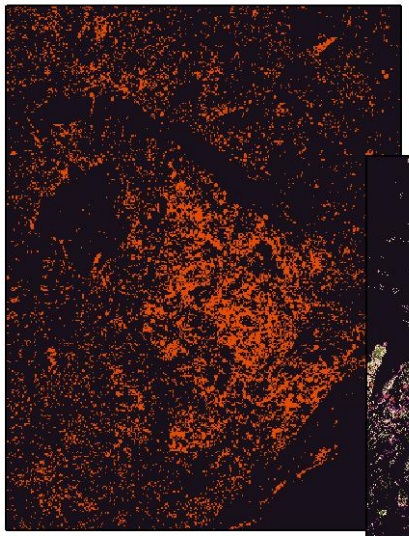


2005

Hurricane Hugo

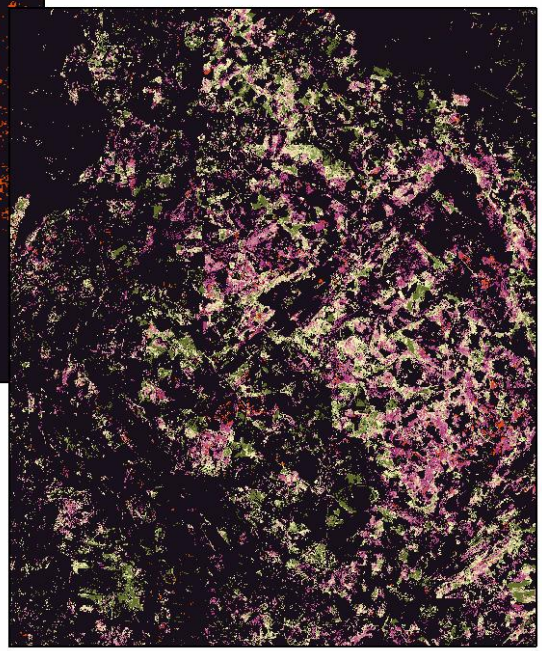


Most recent disturbance



1989-1990 Disturbance

Recovery rate



Science/Applications

- Track evolution of forest management practices over time (more thinning?)
- Quantify riparian forest management in agricultural matrix
- Understand drivers of landscape-level patterns in forest recovery rate, insect outbreak intensity
- Understand ecological precursors to and trends after fire

Key points

- Change detection: Look for the change process, not the change event
- Discrete and continuous-variable phenomena “fall out” of fitting
- Increased SNR → detection of subtle phenomena, screen out noisy phenomena
- No need for pre-screening

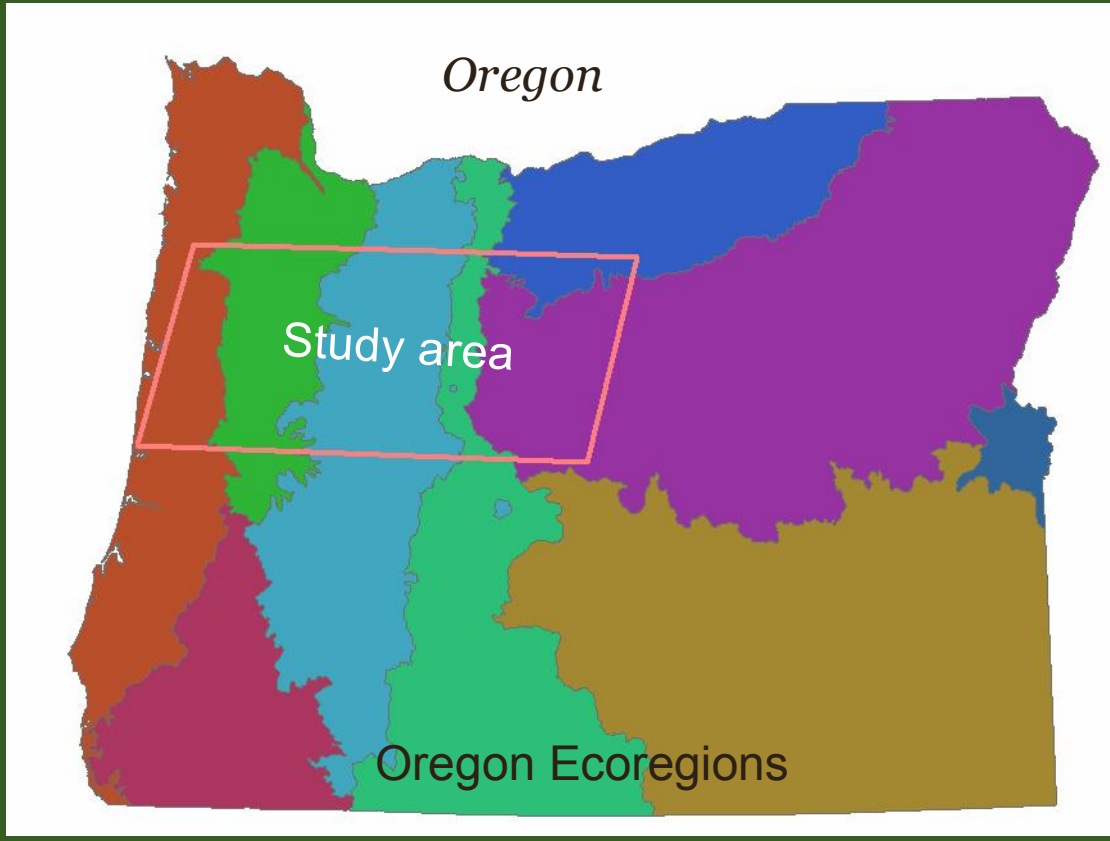
Key point

All of this is possible
only because of the
quality, depth, and continuity
of the Landsat
TM/ETM+ archive!

The End

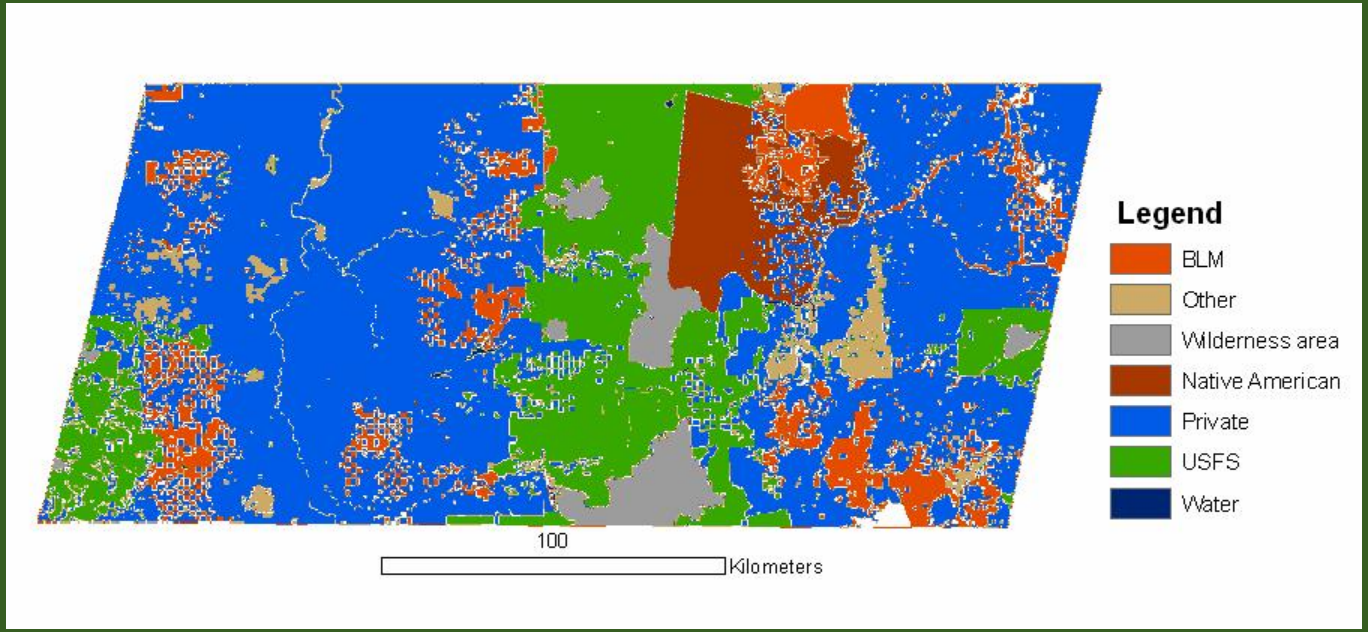
Example applications of method

- Douglas-fir, high-elevation mixed, ponderosa, and juniper forests

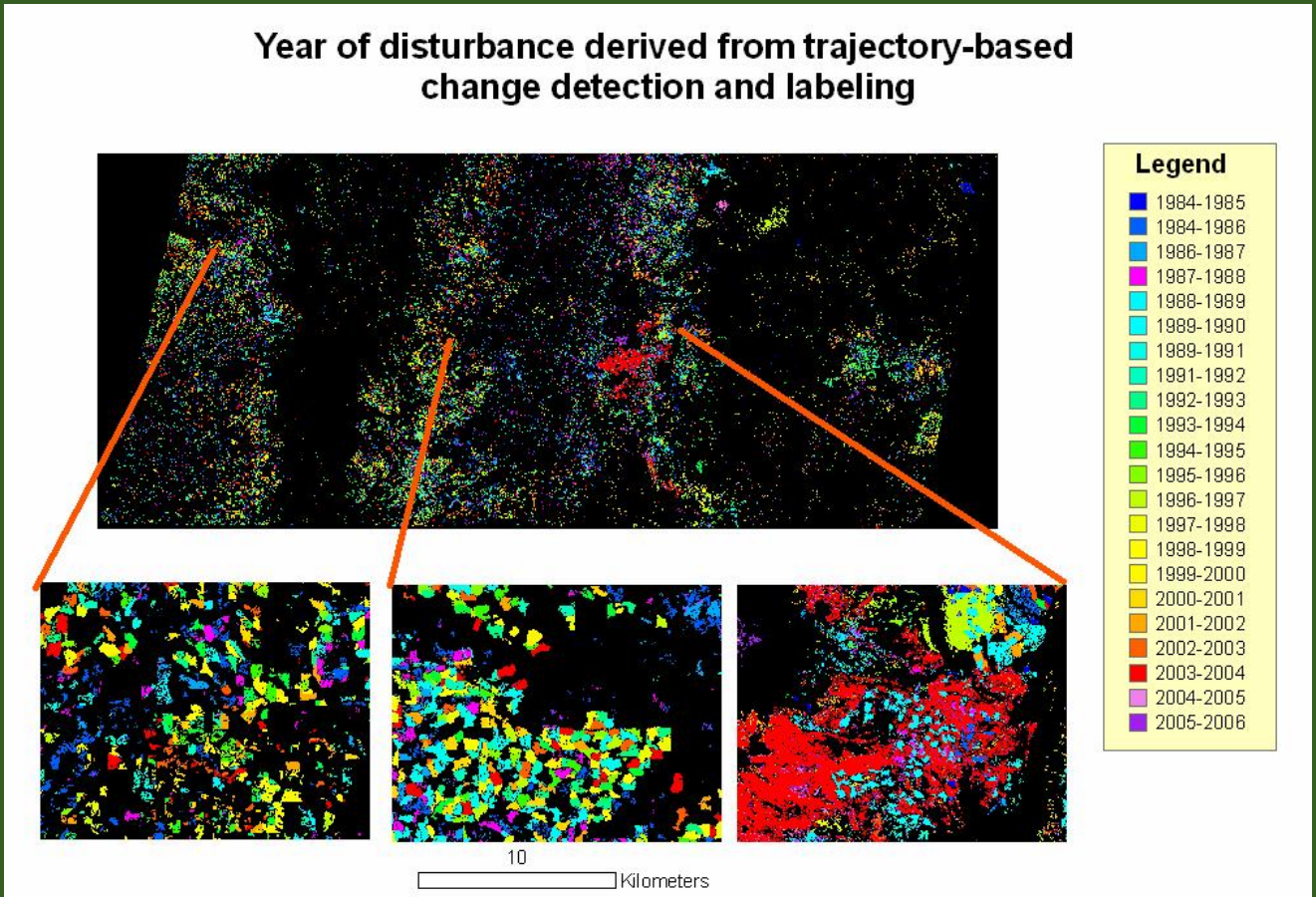


Diverse forest ownership

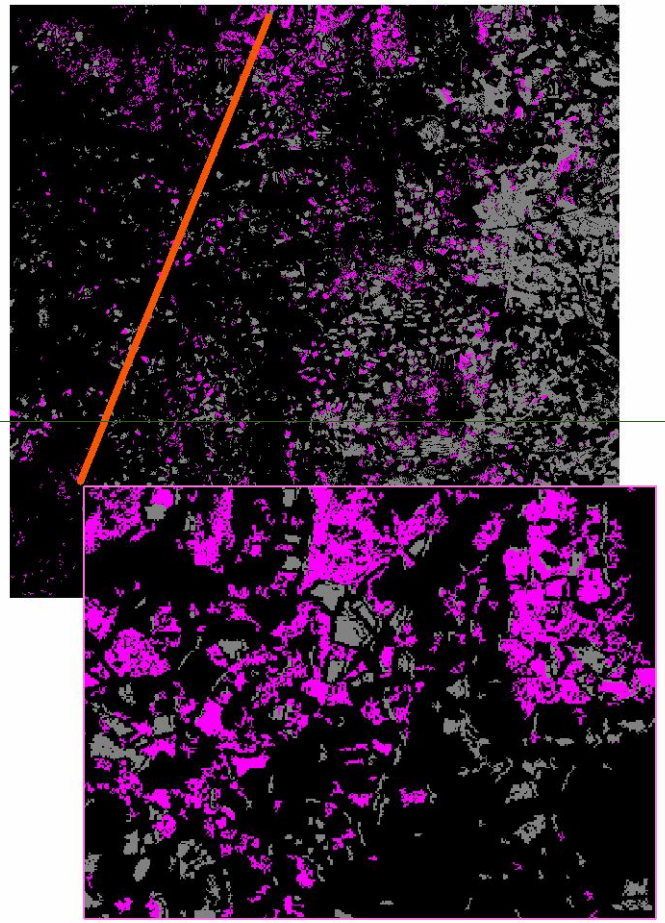
- Private, USDA Forest Service, USDI Bureau of Land Management, Tribal



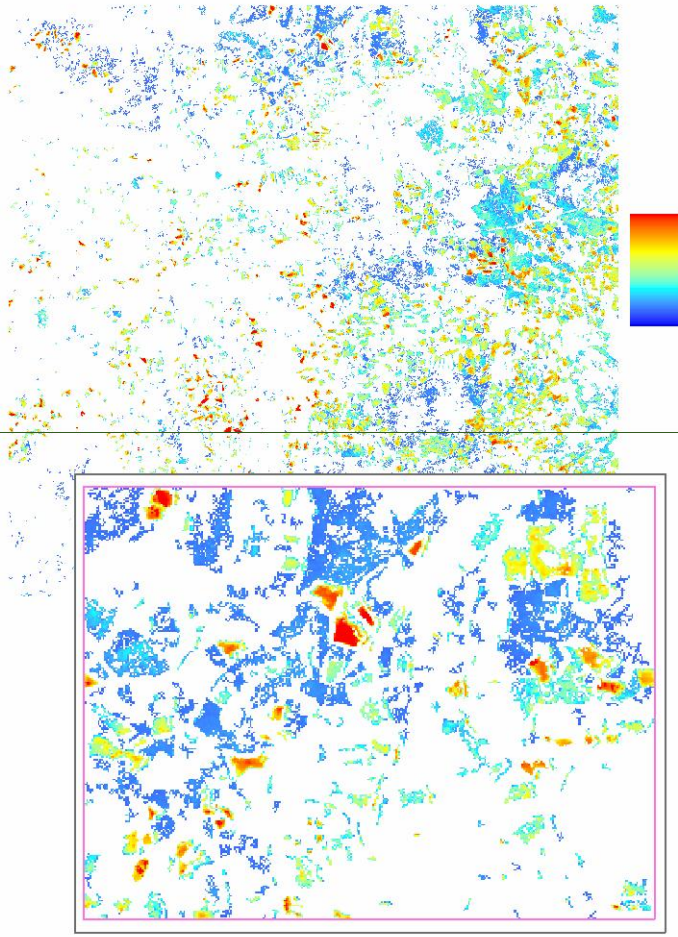
Outputs: Year of disturbance



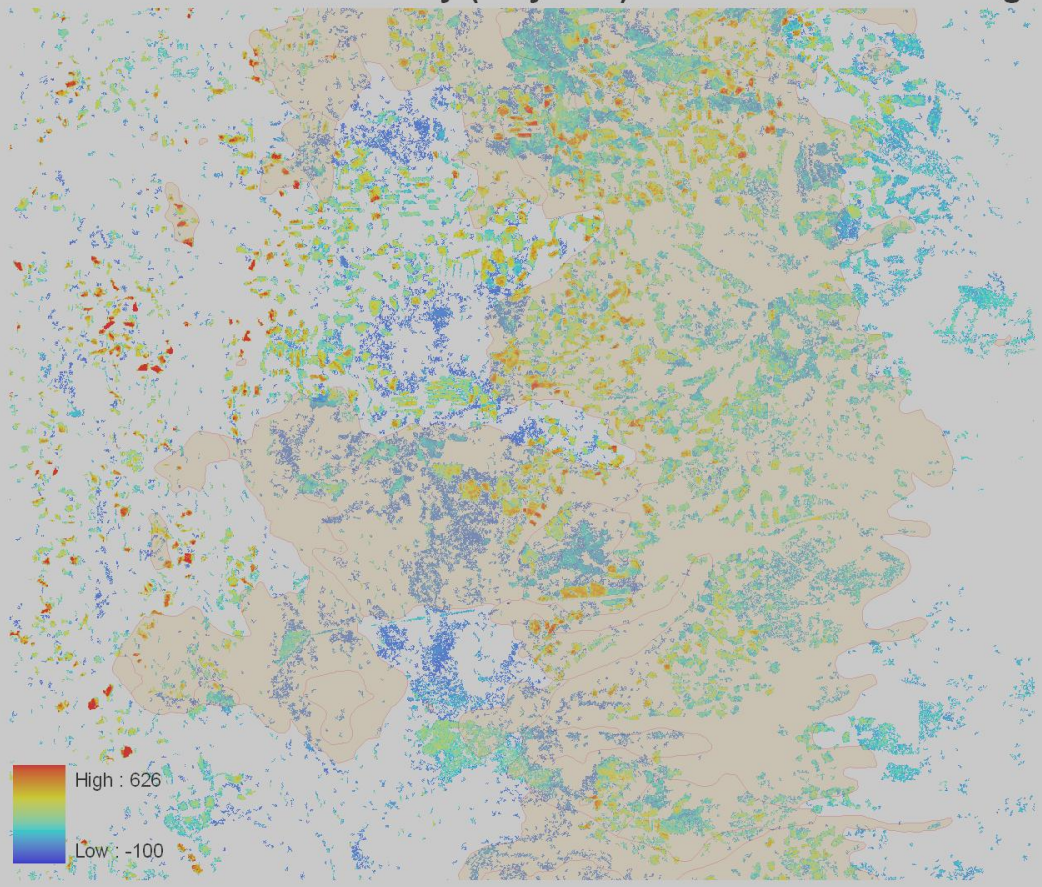
Disturbances in 1988



Disturbance intensity

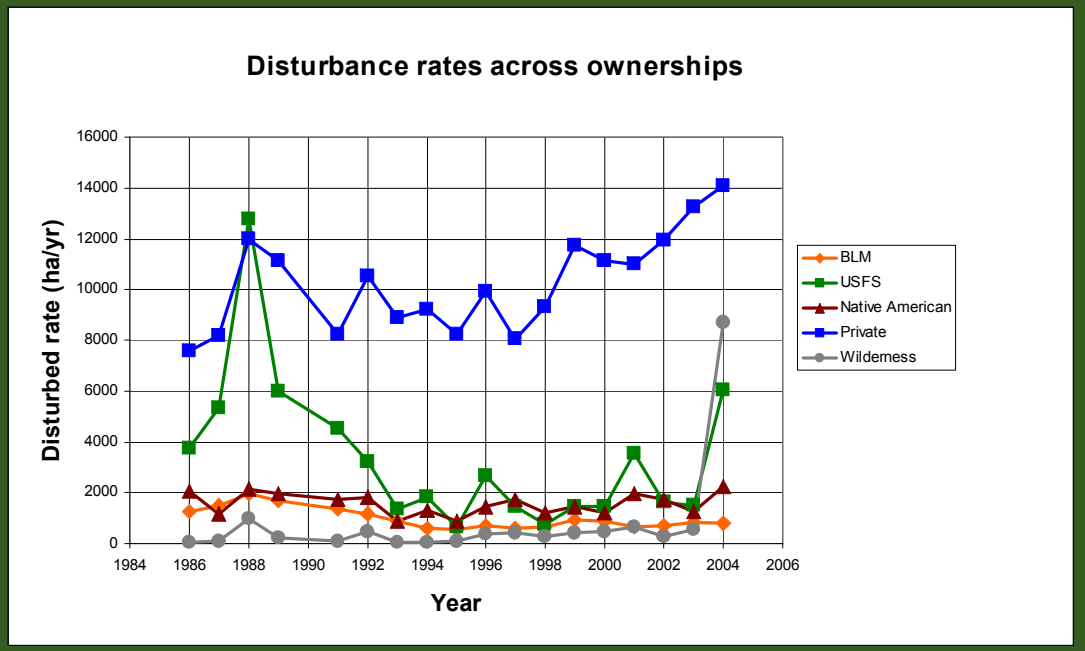


Disturbance intensity (all years) with 1988 FHM Overflight Data

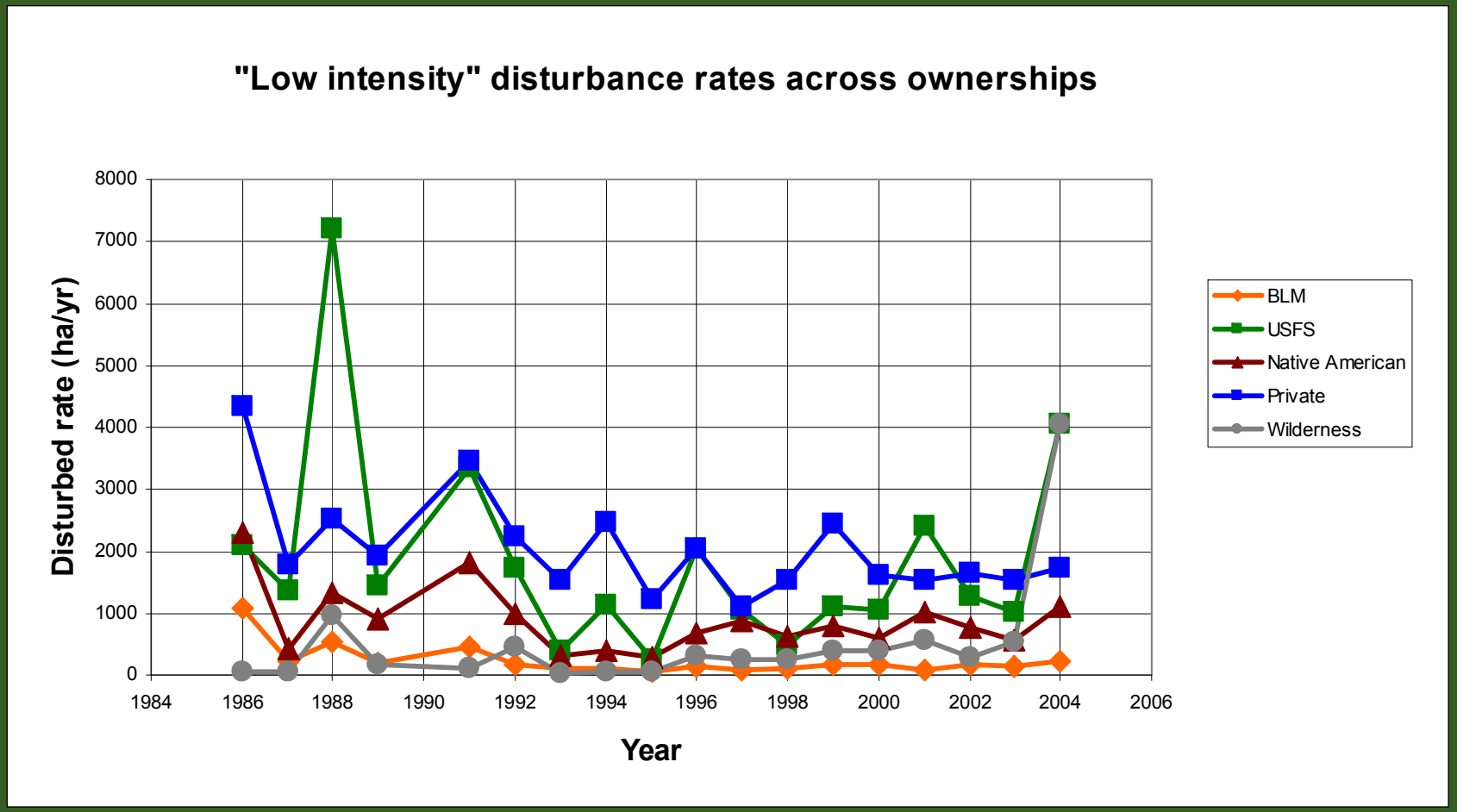


Disturbance rates by owner

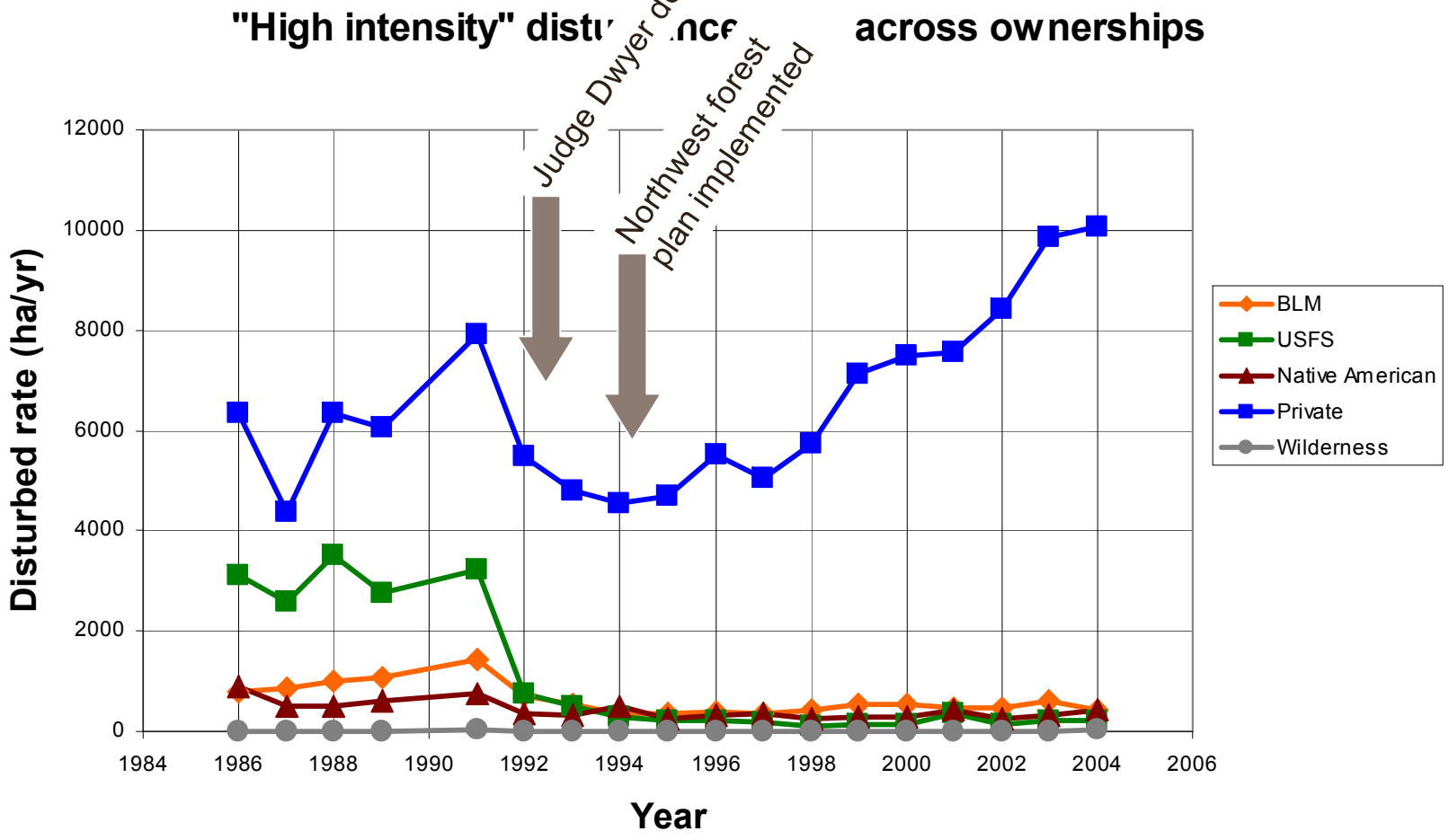
- Areal rates highest on private lands
- Year-to-year variability



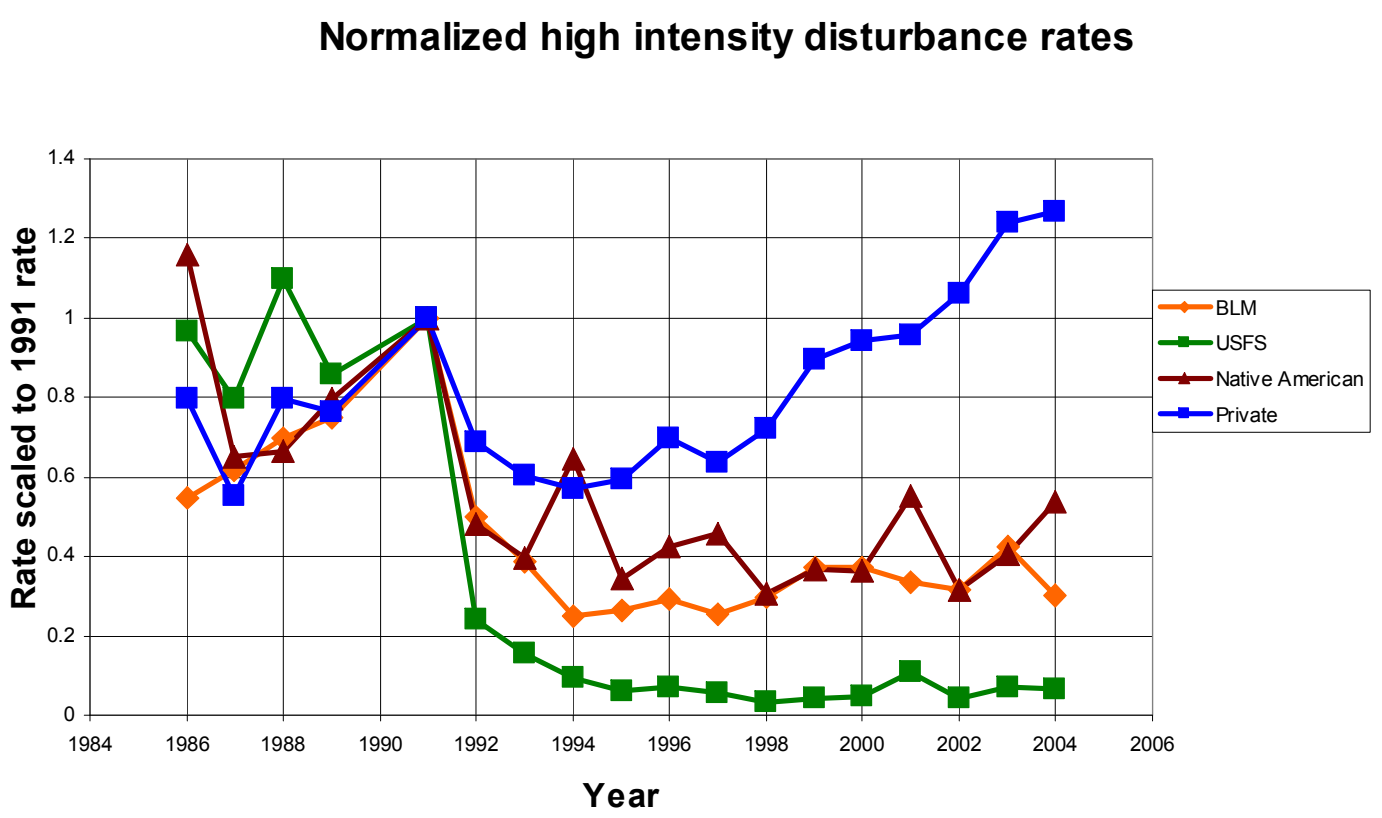
Low intensity disturbance across management regimes



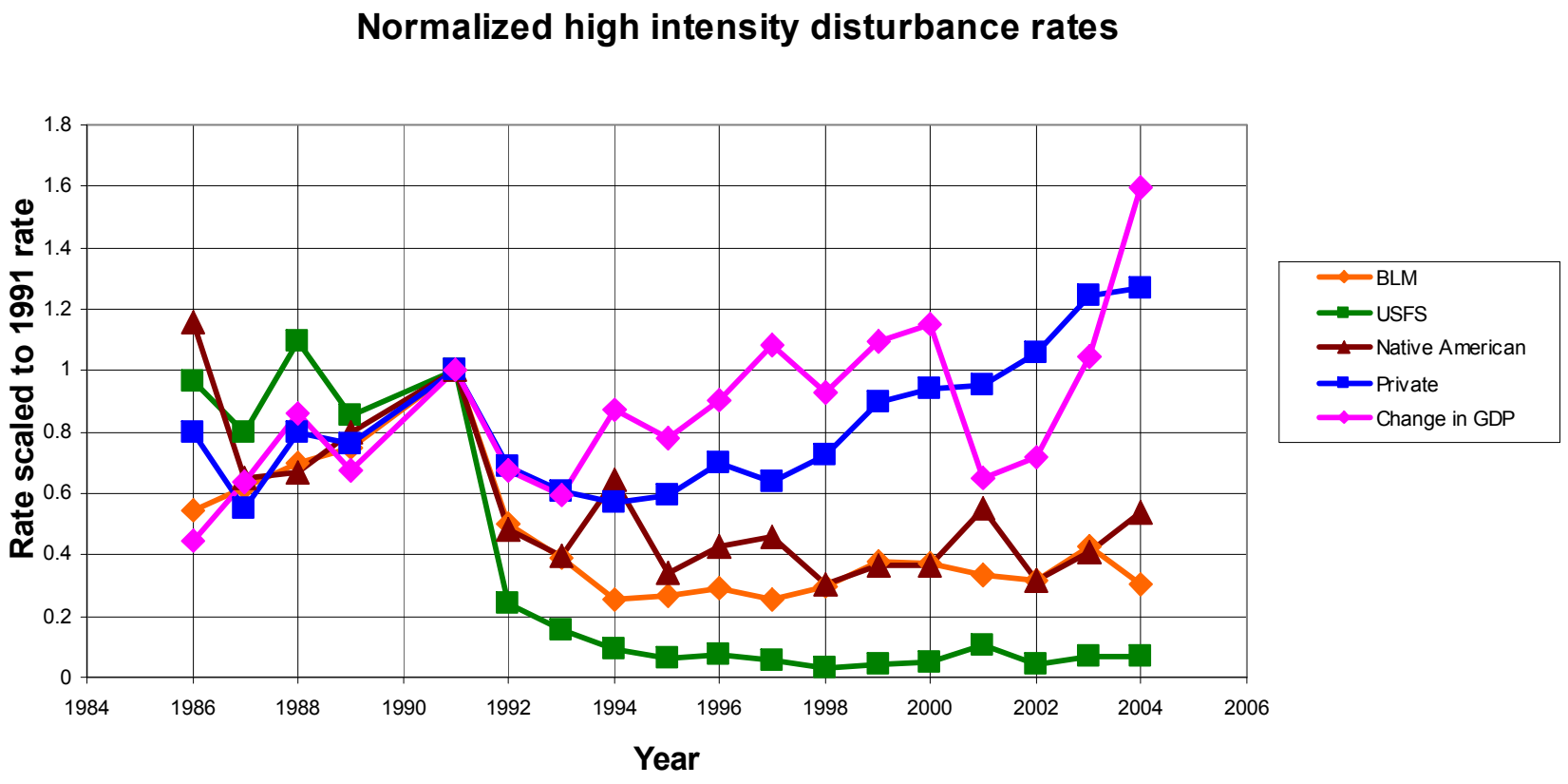
Impacts of policy



Rates normalized to 1991



Impacts of economics



Spatial variation in recovery rates

- Landscape-wide estimates of initial revegetation
- Planned analyses: contrast pixel vs. stand level drivers of recovery rate, including management, climate, soil, etc.